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The effect of the systemic fungicide Aktuan on Collembola under field conditions

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Two applications of Aktuan, with 11 weeks interval, influenced Collembola populations negatively: eleven weeks after the first application total biomass was reduced by more than 40% and eleven weeks after the second application, biomass in the treated plots was still nearly 30% lower. Although there was a clear reduction in individual numbers, not all species were affected to the same extent, and at the same time. Populations of typical fungal feeders (*Hypogastrura assimilis*, *Proisotoma minuta*) nearly collapsed as early as after the first application, while groups inhabiting deeper soil layers or indicating areas with more advanced stages of organic matter decomposition (juvenile *Onychiuridae* and *Entomobryidae*, *Isotoma notabilis*, *Neelus minimus*) were reduced only after the second application. The only species which increased in the fungicide plot compared with the control was *Lepidocyrtus lanuginosus*. Individual numbers of this species, however, were already higher in the fungicide plot before Aktuan was applied.

1. Introduction

In the FRG every year about 32500 t of pesticides are applied. the greatest fraction are herbicides (53% of all pesticides sold in 1988), followed by fungicides (35%) (Korte 1992). Of all the fungicides 3/4 are applied in fruit, vine and hop cultures and thus are concentrated in only 4% of the whole agricultural area (Börner 1983). Since the appearance of fungal diseases, copper fungicides have been used up to now. For several reasons — such as soil contamination, resistance of fungi, development of more specific substances, more and more organic — i.e. degradable — fungicides have been developed. Since their introduction in the early seventies, the importance of foliar fungicides has increased (Frampton 1988). Fungicides can have direct or indirect effects on soil animals. According to several authors (e.g. Bick & Brocksieper 1979, Edwards 1977, Finlay 1985), many fungicides usually have no strong negative impact upon soil animals. Curry (1986) reviewed the toxic effects of broad spectrum fungicides on earthworms, mites and insects, and in Frampton's (1988) investigations foliar fungicides, especially pyrazophos, caused high mortality in Collembola.

In many hop farms some systemic fungicides have not yet been applied, since the treatment of fungal diseases is still carried out using copper compounds. The aim of this study was to investigate the effects of a new organic fungicide on Collembola under the special field conditions of hops, where soil animals are "accustomed to" high amounts of fungicides in general. If systemic fungicides cause any additional effects on species composition or the biomass of soil animals, their application could lead to changes in soil properties and nutrient cycling. Collembola have frequently served as indicators for the effects of pesticides in the soil (e.g. Frampton 1988, Heimann-Detlefsen 1991) and thus have also been investigated in this study.

2. Site and methods

The experimental field was situated in the tertiary hill slopes of Southern Bavaria about 50 km north of Munich. The soil texture was silty loam, the soil type was a calcaric regosol derived from Loess with an A (0–20 cm) to C (20–100+) profile. In the upper 10 cm, soil acidity was at pH 7.3 ($CaCl_2$), the C content was determined as 2.0%, the N content as 0.16% and the Cu content as 71 mg per kg soil dry weight (Winter et al. 1991). The field has been under hops since 1978 and has received about four copper applications per year.

The plant rows had a distance of 3.4 m. Between them, rape was grown as a green manure. Along one plant row, at each side an area of width 3.4 m and length 15 m (50 m^2) was marked out. One side was used as the control, the other was sprayed with 5 l Aktuan solution (0.01%; eq. 1 kg Aktuan/ha) which is equivalent to the dosage normally applied in farming practice. Aktuan contains 10% cymoxanil and 25% dithianon. In each plot, samples were taken four times: 3.8.1989, 26.4.1990, 12.7.1990 and 27.9.1990. The first application of Aktuan took place on 28.4.90, the second one on 14.7.1990. During the applications it was dry and calm, the daily mean temperature in April was around 7 °C, in July around 15 °C.

The samples were taken at random with ten replicates each. The stainless steel cylinders used had a volume of 200 cm^3 (diameter 78 mm, height 40 mm).

The soil fauna was extracted by a newly developed compact extractor which was based on a modification of the MacFadyen-High-Gradient-Extractor described by Andrén (1984). The collecting vessels made of stainless steel were placed on a 12°C cooling unit. The temperature of the sample surfaces was computer-controlled and was raised from 20 to 35°C in the course of five days. Ethylene glycol was used as collection fluid.

The Collembola were warmed in lactic acid and prepared with Marc André No. 2. Under a phase-contrast microscope they were determined to the species level according to Gisin (1960) and Fjellberg (1980). Additionally, all individuals were measured. Based on body length, the biomass was calculated according to Dunger (1968).

3. Results and discussion

Before fungicide application (August 1989 and April 1990) there was good conformity between the plot to be treated and the control. With the exception of single species, individual numbers, biomass and species numbers were nearly identical, so that the initial conditions can be regarded as balanced (Table 1).

In September 1990, after the first application, the population in the treated plot definitely differed from the control: total biomass was more than 40% lower. The effective substances of Aktuan are not toxic to bees (Perkow 1988) and — according to the producer — not toxic to invertebrates, so that any reduction of the Collembola must be caused by indirect effects through the lack of the fungi as a food source.

To demonstrate this, one has to consider the abundances of single species (Table 1). With few exceptions, the individual numbers in the control were distinctly higher than in the treated plot. The species mostly affected is *Proisotoma minuta*, a fungal feeder which is typical to rapidly decaying organic matter with a high N content (Beckmann 1990, Heimann-Detlefsen 1991, Gisin 1960, Zerling 1990). The ecology of *Hypogastrura assimilis* is very similar (Gisin 1960), and thus — together with juvenile hypogastrurids probably belonging to this species — its density was significantly lower in the treated than in the untreated plot (Tables 1–2). However, the population of *H. assimilis* in the control plot was already larger before fungicide application so that it cannot be decided if the reduced individual numbers after treatment are really caused by the fungicide.

Table 1. Individuals (per m^2, calculated by multiplying sum of 10 replicates of 200 cm^3 by 20) and biomass of Collembola in plot treated with Aktuan (before and after treatment) and control plot.

	Test plot				Control plot			
	Before		After					
	Aug 89	Apr 90	Jul 90	Sep 90	Aug 89	Apr 90	Jul 90	Sep 90
Hypogastrura assimilis			140			460	760	60
Hypogastruridae (juv.)							280	40
Tullbergia macrochaeta	20	40					120	60
Tullbergia (juv.)						20		180
Isotoma notabilis	1960	9500	37860	1120	1940	4080	57100	2740
Isotomurus palustris	440	2360	4460	560	240	5620	5860	420
Proisotoma minuta		260	1160			1220	41340	80
Isotomidae (juv.)			180				380	
Lepidocyrtus cyaneus	40	440	2300	8220	620	580	6000	12180
L. anuginosus		140	240	1400	40		600	240
Pseudosinella alba	20			260	40	20	120	260
Entomobryidae (juv.)		200	380			220	620	460
Arrhopalites caecus			20				20	
Bourletiella hortensis		40			20	20		
Neelus minimus	100	1260	2760	760	100	920	5760	3440
Sminthurinus aureus	20	420	20	280	140	240		140
Sminthuridae (juv.)	100	2160	260	880	520	1500	220	980
Biomass (mg/m^2)	28.8	227.4	393.4	249.1	44.1	192.2	701.2	392.3
SE	8.2	68.3	148.0	51.5	11.1	47.9	115.3	98.0

In addition, the following species were found in low numbers (1 or 2 ind): *Onychiurus armatus, Tullbergia sylvatica, Folsomia quadrioculata, Isotoma viridis, Pseudosinella* sp., *Sminthurides pumilis*. 24 ind. were undetermined.

After the second application of Aktuan, total biomass in the treated plot was still distinctly lower than in the control, but this was only significant for onychiurids. Hypogastrurids and *P. minuta* had vanished completely in the treated plots. Among the remaining species, several were significantly reduced (Table 2). Most affected were juvenile *Entomobryidae*, further on *Isotoma notabilis* and *Neelus minimus*. *I. notabilis* is typically correlated with advanced stages of decomposition (e.g. Andrén 1984, Usher 1985, Zerling 1990). There is nothing known about the food sources of *N. minimus*. Since this typical euedaphic species is very small, it probably feeds on bacteria settling on soil particles, as is known in juveniles of other species (e.g. Andrén 1984). One could speculate that they have been affected indirectly by the fungicide treatment, because they could have fed on excrement from fungal feeders or on bacteria growing on decaying fungi.

A third group of species was not affected. *Lepidocyrtus cyaneus* according to Dunger (1956) prefers fungal food. Indeed it was reduced in the treated plots, but not significantly. This may be caused either by alternative food sources or by immigration, since this species is rather mobile. The same is valid for all sminthurids except *N. minimus*. It is not surprising that *Isotomurus palustris* was not affected at all, because it mainly feeds on dead plant material; sometimes also predatory behaviour is reported (Heimann-Detlefsen 1991).

According to Dunger (1956) *Lepidocyrtus lanuginosus* also prefers a fungal diet, but phytophagous behaviour has been observed as well (Hüther 1961). This explains why *L. lanuginosus* was the single species able to increase its population size compared with the control.

Table 2. Kruskal Wallis analysis of significant differences between treatment and control based on number of individuals and biomass of Collembola. * $P \leq 5\%$, ** $P \leq 1\%$, *** $P \leq 0.1\%$. Significant values where treatment was larger than control within parentheses.

	Aug 89	Apr 90	Jul 90	Sep 90
Individuals				
Hypogastrura assimils		*	**	
Hypogastruridae (juv)			**	
Tullbergia (juv)				**
Isotoma notabilis		(*)		*
Proisotoma minuta			***	
Lepidocyrtus cyaneus	*			
L. lanuginosus		(*)		(***)
Entomobryidae (juv)				**
Neelus minimus				*
Sminthuridae (juv)	**			
Biomass				
Hypogastruridae			**	
Onychiuridae			*	*
Isotomidae			*	
Entomobryidae			*	
Total Collembola			*	

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